

Resistance to dynamic and static loading of the implant mounts on its respective implant

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ABSTRACT

Introduction: Implant restorations should endure a variable range of forces over a long period of time. Some commercial brands offer the implant together with an accessory called “implant mount” or “implant holder,” which might be used as a temporary abutment. However, scientific literature in the use of implant holders as abutments for restorations is scarce.

Objectives: The purpose of this *in vitro* study was to compare the load at which implant holders of Implant Direct® and Zimmer® fail under static compression after being subjected to fatigue, and to compare the gap produced between the implant–holder complexes after dynamic loading.

Materials and Methods: The test protocol was based on the recommendation of ISO 14801. Five implant–implant holder assemblies of each brand were subjected to dynamic loading. A load of 250 N was applied at 5×10^6 cycles and at 15 Hz stress frequency (Eden Prairie, MN, USA). The gap (μm) at the interface was measured postfatigue using scanning electron microscopy (S-3700N, HITACHI, Japan), and afterward, static loading was applied and the maximum load (N) after the point of failure was established. Implant–definitive abutment complexes were used as controls. Data were analyzed by means of a central tendency measurement test Mann–Whitney U-test (nonparametric).

Results: There was no difference between both the implant holder groups ($P \leq 0.05$); however, a slight trend of greater resistance was observed for the Zimmer® group. The gap in the interface was greater for Implant Direct® implants, but the difference was not statistically significant.

Conclusion: No significant differences were found in terms of the maximum load under compression or the interface gap after the dynamic loading in the two experimental groups.

KEY WORDS: Dental implant, fatigue, implant abutment, implant holder, implant mount

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INTRODUCTION

Dental implants are subjected to many load cycles during their life, especially those produced during masticatory function. Constant dynamic loading can cause failure, with serious consequences from a clinical point of view. The microspace between the implant and the abutment could increase due to stresses associated with the bending moments generated by the application of cyclic

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loads, and a consequent wear on the interface can occur. This phenomenon and the subsequent plaque retention, result in clinical consequences such as bone loss, periimplantitis, and possible loss of osseointegration.^[1,2] Furthermore, as a consequence, the beginning of a crack could cause a fracture of the thinner parts of the interface,^[3,4] as well as provoke corrosion.^[5] The failure of this system could be caused by several circumstances, from loosening, threading, or fatigue rupture of the abutment screw, to rupture of the abutment itself, being the first of these the most common.^[6,7]

Implant restorations should be able to withstand a variable range of forces over a long period of time, so certain cyclic and static loading protocols are used to evaluate the implant–crown–abutment assemblies, and thus determine the ultimate resistance to fracture and behavior during a constant load of the abutments on implants.^[8] Some commercial brands offer the implant together with an accessory called “implant mount” or “implant holder.” The implant mount is a transitory attachment whose main function is to move the sterile implant from the package to its place in the mouth.^[9] However, in many cases, it is also used as a temporary abutment, which implies that it will be for a long time supporting loads in the patient’s mouth.^[10] The scientific literature has not studied the implant holder under dynamic and static loads, to test their resistance to fracture or failure.

Fatigue (defined as the break or fracture caused by repeated cyclic or applied loads below the yield limit) is viewed initially as microscopic cracks followed by tearing and rupture.^[11] Congruently, fatigue failure is known as the development of these microscopic cracks in areas of force concentration. The ultimate failure results from the final load cycle that exceeds the mechanical capacity of the material. The area that most commonly fails first by the concentration of these cracks is the interface between the abutment and the implant.^[12] The dynamic fatigue tests on dental implants are overseen by 2007 ISO 14801, which systematizes a fatigue test method for single implants and their prefabricated prosthetic components where the functional load to the implant and its components is simulated under the conditions of the “worst-case scenario.”^[13] Although there are no studies on fatigue and flexion-compression resistance evaluating the interface of implant mount and the implant, there are some studies that evaluate the behavior using the implant and the prosthetic abutment.^[14]

Therefore, the objective of this study was to compare the maximum load at which implant mounts fail on their respective implant under a static flexo-compression after being subjected to fatigue. We also attempted to compare the distance in microns of the gap in the

interface of the implant holders between the two implant systems, immediately after applying the cyclic load. The hypothesis of our study is that there would not be differences between the two commercial brands or the implant holders and the definitive abutments within each brand.

MATERIALS AND METHODS

The present research protocol was approved by the Research Commission of the Dental Faculty, along with the Vice Rector’s Office for Research. Two different commercial brands were investigated, as shown in Table 1. For each brand, there were an experimental group using implant mounts and a control group using definitive abutments. The test protocol was based on the recommendation of ISO 14801, bending all samples at 30 Ncm according to the manufacturer’s instructions. Each implant was fixed in a stainless steel jig by means of fixing screws (Machine Shop, Faculty of Physics), with an angulation of 30° between the implant axis and the direction of force, as well as the 3 mm of implant neck exposure. Furthermore, all abutments and holders were modified to have a uniform height of 11mm.

The cycling loading was performed using a MTS® Landmark® universal servo-hydraulic testing machine (Eden Prairie, MN, USA, maximum loading capacity: 25 kN). A load of 250 N was applied at 5×10^6 cycles and at 15 Hz stress frequency, to simulate approximately 25 years of use. The appropriate initial load resembles to 80% of the failure load obtained in a static test previously performed, using the same test geometry. The load was applied unidirectional by a steel piston for a total of 93 h and a stable room temperature of $20^\circ \pm 5^\circ\text{C}$ [Figure 1].

After the dynamic test, all samples were examined with scanning electron microscopy (SEM) (S-3700N, HITACHI, Japan) and it was analyzed if the permanent deformation of the specimen, the loosening of the whole unit, or the fracture of any component occurred in the

Table 1: Group distribution

Group	Manufacturer	n	Description
IH Z	Zimmer®	5	Implant holder + 13×3.7 mm Tapered Screw-Vent® implant
IH ID	Implant Direct®	5	Implant holder + 13×3.7 mm Implant Direct® Legacy 3® implant
DA Z	Zimmer®	2	Definitive straight standard prefabricated abutment + 13×3.7 mm Tapered Screw-Vent® implant
DA ID	Implant Direct®	2	Definitive straight prefabricated abutments with + 13×3.7 mm Legacy 3® implant

interface area of the implant holder and the implant. Furthermore, SEM images were used to measure the interface between the implant mount and the implant platform, placing a reference point in each component. Two images were taken for each sample at $\times 20$, to observe the deformation of the specimen. A third image at $\times 300$ was used to measure the interface. The measurement of the gap in microns found in the interface of the abutments and the implant was registered after the cyclic loading.

After the SEM images were taken, a static flexo-compression load test was applied to each specimen of the experimental and control groups by the same unidirectional steel piston, and loaded with compression at a speed of 0.5 mm/min until the ultimate failure. The load was continuously monitored in the computer and the maximum load at which the specimen failure occurred was recorded. A Levene test was used to assess the homogeneity of the variances, and afterward, a Kolmogorov–Smirnov test was applied to check for normality distributions. A central tendency measurement test Mann–Whitney U-test (nonparametric) was performed for each of the Zimmer® and Implant Direct® samples including definitive abutments and implant mounts, to determine if there was a difference in ultimate failure within each group. In addition, this test was also performed to assess the gap created at the interface after undergoing the fatigue test.

RESULTS

Descriptive observations suggested that Zimmer® implant mounts' survival was greater than the survival for Implant Direct® implant holders. The Levene and Kolmogorov–Smirnov tests, indicated that nonparametric tests were needed to analyze the data. The Mann–Whitney U-test showed that the null hypothesis ($P > 0.05$) was accepted,

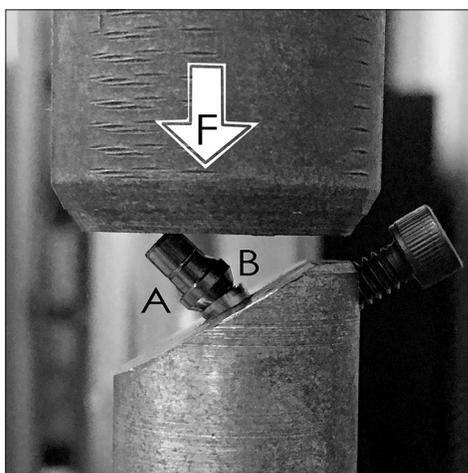


Figure 1: Cycling loading setting. A: Compression site. B: Tension site, later observed by SEM. F: Direction of force

indicating no statistically significant differences between the load to fracture for the Implant Direct and Zimmer implant mounts [Table 2].

SEM images taken after the fatigue test, showed that the average interface for the Zimmer® implant system was $233 \pm 112.19 \mu\text{m}$, while the gap for the Implant Direct® implant system was $276.4 \pm 261.40 \mu\text{m}$, indicating that there was no statistically significant difference between the implant holders [Table 3]. Particularly, the specimens showed that the implant collar was deformed in all samples in the area of tension [Figure 2]. On the other hand, in two of the samples, a fracture of the implant collar was identified in an area close to the compression area, which classifies them all as failed samples (ISO 14801) [Figure 3].

DISCUSSION

This *in vitro* study evaluated the maximum load at which implant mounts fail under a static flexo-compression after being subjected to dynamic loading. We also evaluated the distance in microns of the gap in the interface of the implant–implant holder complex after applying a cyclic load, and see whether there is any statistically significant difference between two commercial brands, namely Zimmer® and Implant Direct®.

The results of this study showed the survival of 12 samples after the cyclic test; on the other hand, the other two samples suffered fractures in the implant collar, which coincides with ISO 14081 stipulations, and are therefore classified as failed. Although the ultimate

Table 2: Fracture load in *n* according to experimental group

Group	Median (<i>n</i>)	SD	Minimum value (<i>n</i>)	Maximum value (<i>n</i>)
IH Z	2065.2 ^{A, C}	93.1	1987	2226
DA Z	1395 ^{A, D}	811	822	1969
IH ID	1681.2 ^{B, C}	357.35	1274	2031
DA ID	1209 ^{B, D}	11.31	1201	1217

Values with different superscript letters are significantly different from each other ($P \leq 0.05$). SD=Standard deviation.

Table 3: Gap after fatigue loading (μm) according to experimental group

Group	Median (μm)	SD	Minimum value (μm)	Maximum value (μm)
IH Z	233 ^{A, C}	112.2	37	317
DA Z	221 ^{A, D}	62.2	177	265
IH ID	276 ^{B, C}	261	41	701
DA ID	160.5 ^{B, D}	60.1	118	203

Values with different superscript letters are significantly different from each other ($P \leq 0.05$). SD=Standard deviation.

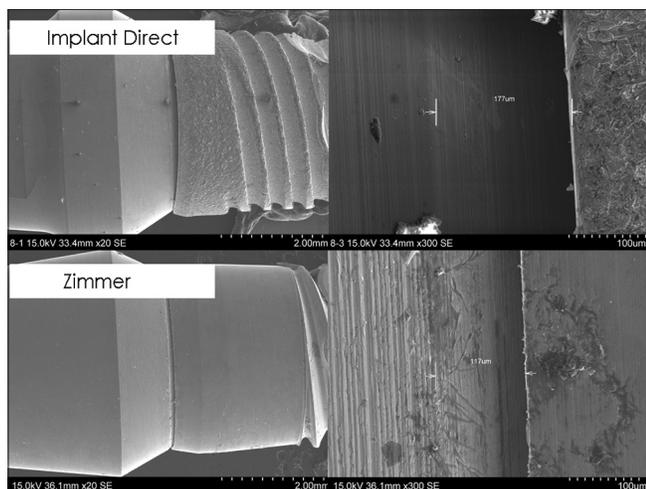


Figure 2: Gaps produced on implant mount–implant complex after fatigue loading in the area of tension

strength of the implant mount of both brands differs, the statistical results showed that there were no significant differences in these values between both implant systems to a static load, therefore, the null hypothesis is accepted. The latter stated that there would not be any differences in the fracture load of the two different implant mounts between each other or the definitive abutments of the same implant brand.

One possible limitation and reason that favors this scenario was the relatively low sample of five specimens per group.^[14] Nevertheless, different authors have also performed fracture tests using this sample size, as is the case in Dittmer *et al.* where they use six different implant groups with five samples each.^[8] Furthermore, in other studies, only five samples were used for flexo-compressive load.^[15-18] No previous reports in the literature compared Implant Direct® and Zimmer® implant mounts under fatigue tests.

The importance of this evaluation relies on the clinical fact that implant mounts can be used as a provisional abutment,^[10] even though there are no studies in the literature that justify the use of this component to replace the definitive abutment, and also to prove their use for longer periods of time. The ultimate strength for Legacy 3® implant holders (1681.2 ± 357.35 N) and Zimmer® implant holders (2065.2 ± 93.11 N), shows excellent resistance of these attachments under axial and lateral forces. It is accepted to compare the implant mounts of both brands with the definitive abutments in terms of the maximum resisted loads, since the cross section and the material characteristics in the failure zone are equal. These results offer higher values than those obtained in studies with similar methodology. Kim *et al.* compared three zirconia abutments under a static load, showing that the group with the highest values was

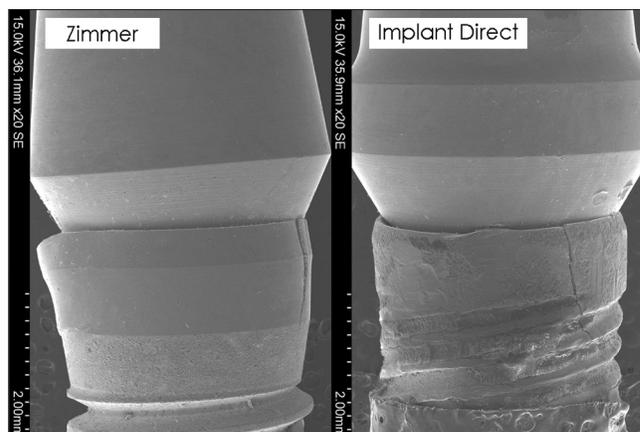


Figure 3: Failed specimens after cycling loading

the Lava abutment (729.2 N). Although the behavior of the fracture was different, there was no significant difference between the groups.^[19] Pedroza also reported a significantly higher fracture resistance for the Zimmer® implants (1197 N).^[20]

According to Yilmaz *et al.*, only Zimmer® Tapered Screw-Vent® implants were used, but five abutments of other brands were evaluated until the fracture of the system, including a Zimmer® abutment and an Implant Direct® abutment. The findings of this study showed significantly greater resistance to fracture of an Implant Direct® abutment of 1104.95 N.^[21]

When performing the static flexo-compressive load test after the cyclic load test, a greater advantage of the fatigue data is obtained because initially the dynamic load is clinically more relevant as it resembles the real situation of chewing, while the static failure helps to locate the weak points of the system, as well as differentiate the implant–abutment complexes.^[2]

The second characteristic analyzed in our investigation was the gap between the holder and the implant after the cycling loading. According to Butignon, the effect of the cyclic loading on the abutments observed by SEM images can be considered one of the most important findings due to the structural damage originated after the tests.^[22] Although it is not a postfatigue requirement stipulated by ISO 14801, some articles evaluated the fractured surface of screws and abutments by SEM or polarized light microscopy, and thus determined the origin and propagation of the crack.^[1,6,23-25]

The ISO Standard provides different definitions of failure that may occur after the cyclic load; these are: (1) when it exceeds the elastic limit of the material and a permanent deformation of the sample is observed, (2) when the implant assembly is loosened off, and (3) when the fracture of any component occurs.^[13] The present study

evaluated by SEM the deformation after the fatigue test and also the gap in the interface between the abutment and the implant, since this could mean that the cyclic load caused a deformation of the system. In our study, the Zimmer implant holders' specimens showed gaps in a range of 37–317 μm , while Implant Direct specimens showed a more variable gap distance with a range of 41–700 μm . On the other side, the gaps depicted in the specimens with definitive abutments ranged between 118 μm and 265 μm for both brands.

Tsuge evaluated the marginal fit and size of the microgap, measuring it with a laser scanning microscope and using five different implant systems. It was found that the average vertical discrepancies varied from 22.6 to 62.2 μm .^[26] Grobecker-Karl meanwhile says that the normal vertical opening at the interface with the properly torqued attachments is between 3.93 and 30.82 μm .^[27] On the other hand, Baldassarri found that the titanium abutment attached to a titanium implant exhibited a smaller gap of ≤ 3.5 μm , compared to the zirconia abutments that presented a gap of 1.5–34.3 μm .^[28]

An important advantage in our study was that we used one implant per specimen complex. Some other studies employed implant analogs or used only one implant per experimental group for fatigue loading. However, we considered that this proposal would not be clinically representative and also because fatigue loading would damage the implant so that it should not be used again for another specimen. Future investigations might employ strain gauges to obtain detailed information of the deformations produced during cycling loading.

CONCLUSIONS

The present study showed that both implant-implant holder systems suffer a similar deformation after cycling loading, however, the final load necessary to fracture the complex shows that both brands offer implant mounts capable to resist the load of a provisional restoration. No statistically significant differences were found in terms of the ultimate strength supported under flexo-compression or in terms of the interface gap after the dynamic loading of the two implant mount systems.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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